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INTERIM REPORT OF FLUORIDE POLLUTION IN GLACIER NATIONAL PARK

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INTERIM REPORT OF FLUORIDE POLLUTION IN GLACIER NATIONAL PARK

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SUMMARY

In this report we present data and inferences pertinent to Glacier National Park drawn from vegetation collected in July 1970 and analyzed for injury and total fluoride content. Samples collected along radii extending from the Anaconda Aluminum Company reduction plant at Columbia Falls, Montana, into Glacier National Park showed conclusively that injury caused by fluoride pollution to plants is occuring in the Park, and that the Anaconda Aluminum Company is the responsible agent. We explain the concept of injury index and establish the control level as 0.006. Normal levels for total fluoride in plant tissue were found to be 10 parts per million or less. In Glacier injury indices were found greater than 0.100 and fluoride levels higher than 70 p.p.m. Radial profiles readily indicate the point source of pollution as well as the direction of travel of the pollutant. The most serious injury occurs on the southwest face of the Apgar Mountains and the southwest face of the Belton winter range. Fluorides in all vegetational types sampled represent a serious threat to wildlife in the affected area.

INTRODUCTION

During early spring of 1970 we developed a study plan to evaluate fluoride pollution in the vicinity of Columbia Falls, Montana (Carlson and Dewey, 1970).[1/] By agreement[2/] the Insect and Disease Branch is responsible for insect and disease evaluations in Glacier National Park. Because air pollution is scientifically classified as a noninfectious plant disease, we included Park lands in the study outline.

In this report we present results and conclusions pertinent to Glacier National Park based on data collected during the first sampling period of July 1970.

1/ Carlson, C. E. and J. E. Dewey. Study plan for the evaluation of fluoride damage to ecosystem segments on National Forest land in the vicinity of Columbia Falls, Montana. USDA, Forest Service, Region 1. 1970.

2/ Agreement between the United States Department of Agriculture and the United States Department of the Interior for forest insect and disease surveys and control on lands of the U.S. Department of the Interior. Title 1531.01.

METHODS

Ten radii were established extending from the Anaconda Aluminum Company reduction plant into surrounding forested lands. Direction of each radius was assumed on the basis of suspected wind patterns and topography. On all radii seven plots were established, one at each of the distances one-fourth, one-half, 1, 2, 4, 6, and 8 miles from the plant. Because radii 4, 5, and 6 extended into Park lands, additional plots were established at 10, 12, and 14 miles on radii 4 and 5 and at 14 miles on radius 6 (fig. 1). Each plot was 6.6 feet wide by 66 feet long (1/100 acre). Vegetation representative of grasses, herbs, shrubs, and conifers was collected on each plot and brought to the Forest Service laboratory in Missoula, Montana, for processing. Processing involved (1) on herbs, shrubs, and conifers, a visual estimation of number of leaves showing fluoride burn symptoms and proportion of length or area burned on individual leaves, and (2) preparation of a subsample for chemical analysis for total fluoride in the tissue. The subsample included at least one representative each of grass, shrub, herbaceous, and coniferous material. All injury and chemical determinations done on coniferous material were done separately on 1969 and 1970 growth. All chemical analyses were done by WARF.[3/] Thus, the collection of data on each plot was designed to estimate injury to and total fluoride in plant tissue. In addition, a subsample of coniferous needle tissue was selected for histological analysis of internal injury using the techniques outlined by Gordon (1970). Because radii 4, 5, and 6 extended into Park lands, this report will deal mostly with data collected on these radii. In addition to data collected on radii, a series of "special samples" from areas suspected of sustaining fluoride injury were collected, 11 of which came from Glacier Park. Special samples were processed as described previously. Also, six control plots were established, three of which were located 30 miles south of Columbia Falls near Swan Lake and three 15 miles west of Kalispell, Montana, near Ashley Lake. Data collection on control plots was the same as for radial plots.

Concept of Injury Index

We found the data collected on visual injury could be most effectively presented in the form of an "injury index" (I.I.). As mentioned previously, for all samples except grasses, we first estimated through routine procedures the proportion (P) of leaves (or needles) showing burn symptoms. We next estimated the ratio (R) of burn on individual leaves or needles. The product (PR) would be an estimation of the total amount of tissue burned for foliage of a given year. Arithmetically, the possible range of values for I.I. is 0.000 to 1.000.

3/ WARF - Wisconsin Alumni Research Foundation. All analyses were given in parts per million (p.p.m.) fluoride on a dry weight basis.

RESULTS

Control Data

Fifty-seven separate vegetational samples were chemically analyzed for total fluoride. The average fluoride for all samples was 7.10 p.p.m. A 95 percent confidence interval is given as 6.00 - 8.20. In other words, except in chance occurrence 5 percent of the time, any value over 8.20 would be regarded as excessive fluoride. In table I-A we have broken the data into components for shrubs, 1969 and 1970 conifer tissue, herbs, and grasses. For all groups except grasses and herbs, the high end of the confidence interval is less than 10 p.p.m. Because the grass and herbs were represented by a small sample size, we conclude that for all vegetation in the study area, 10 p.p.m. fluoride is a valid control level at the 95 percent level of confidence, and the sample was statistically sound accepting 20 percent variation at the 95 percent level of confidence. We also analyzed control data by averaging all fluoride and I.I.'s for each plot (table I-B). The results supported a control fluoride level of 10 p.p.m. and I.I. of 0.006. In figure 1 we depict a profile of control data. The figure is a dual-ordinate graph with I.I. represented on the left ordinate and total fluoride on the right. The points defining the graph are plot averages for total fluoride and injury indexes. In other words, values for fluoride and I.I. were averaged irrespective of plant species for each plot. The data was plotted on logarithmic paper to accentuate small values. It is easily seen from the graph the plot averages for fluoride do not exceed 10 p.p.m. and that I.I. does not exceed 0.006 except in one instance. The average I.I. for all control samples was 0.001. Thus, we arbitrarily established 0.006 as a control level and tested it by nonparametric analysis on all data collected in the study. We found that for all samples having a chemical analysis and with an I.I. of 0.006 or greater, 135 exceeded 10 p.p.m. fluoride, nine were less. Thus, the I.I. of 0.006 or greater was associated with elevated fluoride levels about 94 percent of the time, indicating it would be a reliable parameter for the study.

Radii Data

We believe that plot averages for fluoride and I.I. represent the most stable method to present data collected in this study. Because shrubs, herbs, grasses, and conifers were chemically analyzed in about the same proportion from all plots, the means will represent true differences or similarities between plots. Again, graphic representation of the data is quite effective on logarithmic paper as smaller values tend to be emphasized. Figures 3, 4, and 5 are, respectively, dual ordinate graphs depicting profile of radii 4, 5, and 6. Table II shows the data used for the graphs. The left ordinate represents injury index on a scale from 0.001 to 1.00; the right, fluoride in p.p.m. on a scale from 10 to 1000. The abscissa represents plots in distance from the aluminum plant. A horizontal dotted line depicts the control level for I.I. and

the abscissa the control level for fluoride. On radius 4, plots at distances 6, 8, 10, 12, and 14 miles were on Glacier Park lands. As shown by the graph, fluoride levels were highest near the aluminum plant, decreasing logarithmically to 10 p.p.m. at the 6-mile plot. Fluoride levels then rose to 13.3 p.p.m. at 8 miles, 19.7 at 10, 17.0 at 12, and decreased to 6.9 at 14 miles. In general, injury was highest near the plant and decreased sporadically at the distant plots. High injury was found at the 8-mile plot and was associated with elevated fluoride. The I.I. of 0.008 at the 14-mile plot is not considered as fluoride injury because of the low fluoride content. Topography is hypothesized as the main factor affecting the rise in fluoride levels and I.I. at the 8, 10, and 12-mile plots. The 6-mile plot was located in the valley of the North Fork of the Flathead River (fig. 1). Plots at 8, 10, and 12 miles were located up the slope from the 6-mile plot between elevations of 4,200 to 4,800 feet m.s.l. (mean sea level). Quite likely the pollution, carried by the air, travels from the source over the top of Teakettle Mountain, part way down the east face of Teakettle, then floats across the North Fork Valley at about 4,000 feet before intercepting the Apgar Range.

Plots at 10, 12, and 14 miles on radius 5 were contained within the boundaries of Glacier Park (fig. 1). Figure 4 depicts the injury and fluoride profiles for this radius. As for radius 4, fluoride levels decrease logarithmically to 17.4 p.p.m. at the 10-mile plot, increase to 24.3 at 12 miles, and decrease to 7.5 at 14. High injury was recorded at the 12-mile plot and was associated with elevated fluoride levels.

Again, we strongly believe the rise in fluoride at the 12-mile plot was influenced by topography. The 10-mile plot was located at West Glacier, the 12 at 4,300 feet m.s.l. upslope on the Belton winter range.

In figure 5 we show a profile of radius 6. Only the 14-mile plot was located in the Park; there were no plots at 10 and 12 miles. As on the other radii, fluoride levels were highest near the point source and decreased logarithmically with distance from the plant. Although no injury was recorded at 14 miles, fluorides were excessive at 17.8 p.p.m., indicating pollution is occurring in the Middle Fork Valley.

We must make special mention of some grass samples collected on the radii in the Park. On radius 4, plot 8, the grass had 103 p.p.m. fluoride; on radius 4, plot 9, 71.5 p.p.m.; and on radius 5, plot 9, 72.5 p.p.m. (Plot 8 is 10 miles from source and plot 9 is 12 miles.) These are high readings and probably are explained in that some 1968 and 1969 foliage was included. However, ecologically the sample does represent forage available for mammals in the area.

Special Samples

Special samples were collected at two places on Park lands where visible injury by fluorides was highly suspect. Data is given in table II. At

the old Flathead Ranger Station data was variable but serious injury was found on 1969 needles of lodgepole pine and Douglas-fir and was associated with high fluoride levels as indicated by 66.3 p.p.m. in Douglas-fir. Ponderosa pine and lodgepole pine foliage was collected 2 miles northeast of the Ranger Station on the southwest face of the Apgar Mountains at an elevation of 3,900 feet m.s.l. We found elevated fluoride associated with characteristic needle tip burn on the lodgepole but not on the ponderosa.

Number of Samples

One hundred and four samples from Glacier were analyzed for total fluoride during the July 1970 collections, and 225 were analyzed for injury index.

Histological Analyses

Typical internal symptoms were found in all pine needles exhibiting external symptoms of injury and elevated fluoride levels. Specifically, they include death and granulosis of stomatal mesophyll cells, inflation of transfusion parenchyma, collapse of phloem and transfusion elements, hypertrophy of epithelial cells, and hypertrophy of nuclei (Gordon, 1970).[4/]

CONCLUSIONS

Based on data collected during July of 1970, we have found that fluoride pollution is real in Glacier National Park. Visible injury (tip necrosis of needles and marginal necrosis of leaves) is common along the southwest face of the Apgar Mountains and on the southwest face of the Belton winter range. Elevated fluoride levels are the rule and occur as high as 66 p.p.m. in conifer needle tissue. All vegetation collected in this area, including grasses, herbs, shrubs, and conifers, had high fluoride readings. Some of the grass samples had over 70 p.p.m. fluoride, or more than twice as much as allowed by State law. We are seriously concerned about possible fluorosis in wildlife in the area due to feeding on polluted vegetation because of the high fluoride levels in vegetation.

Radial sampling originating at the Anaconda Aluminum Company plant indicates the source definitely is the reduction plant. The fluorides emanate from the plant, are carried northeastwardly over Teakettle Mountain toward and into Glacier National Park, causing injury to vegetation and possibly to animals. We believe the data is biologically sound, unbiased, and accurately represents the situation as it occurs in Glacier National Park.

4/ Gordon, C. C. Damage to Christmas trees near Oakland, Maryland, and Mountain Storm, West Virginia. University of Montana Report, Botany Department. 1970.

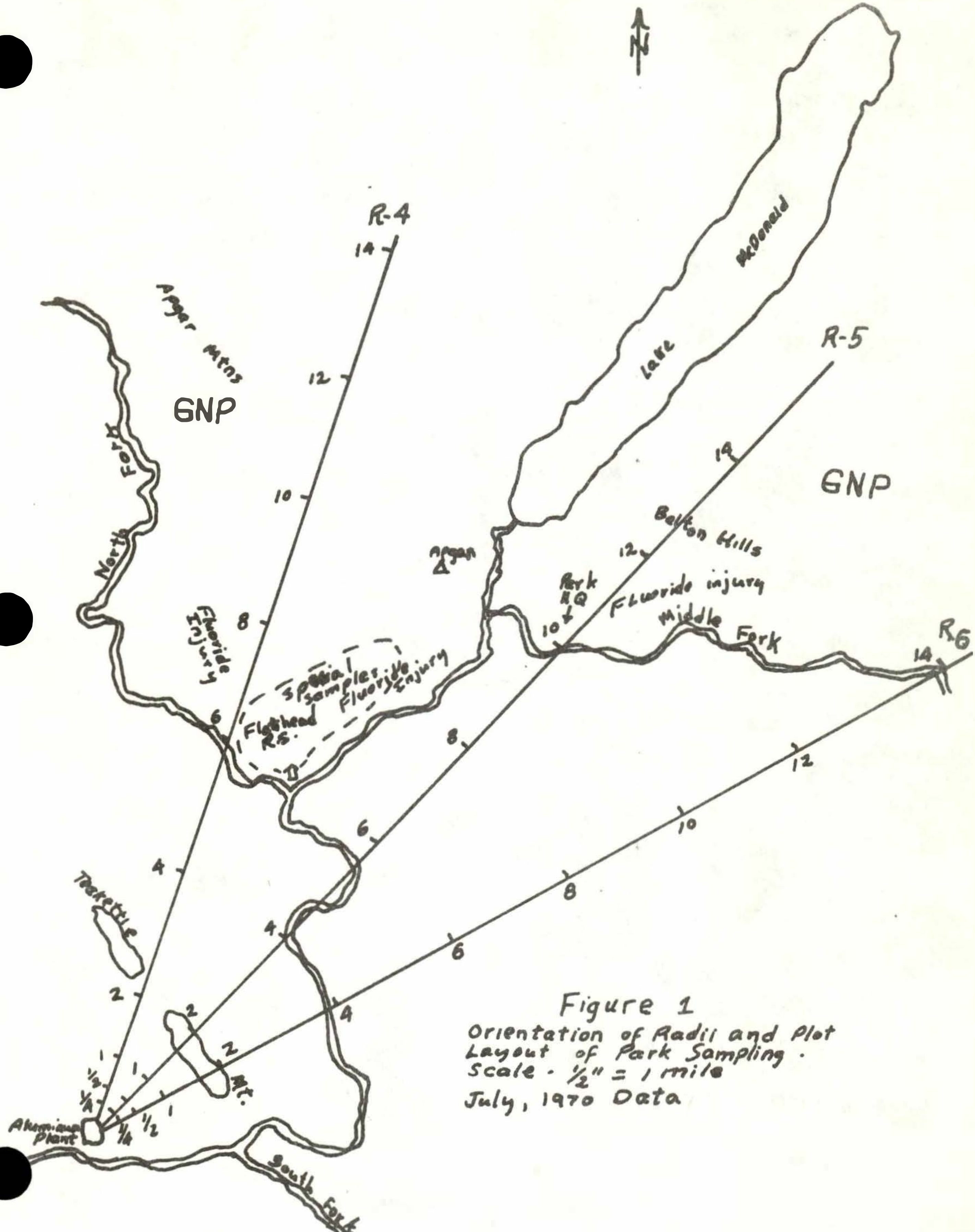
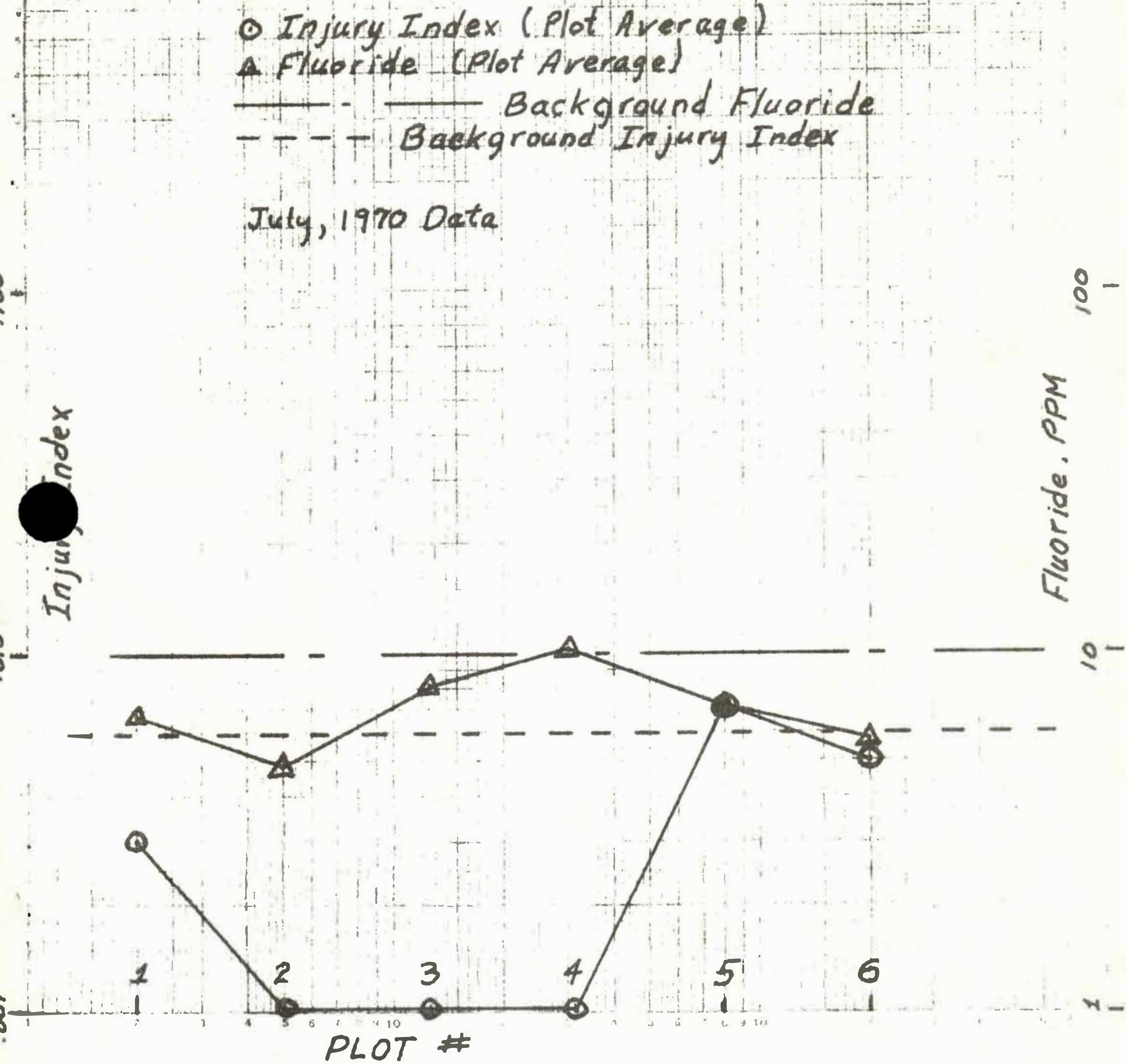


Figure 1
Orientation of Radii and Plot Layout of Park Sampling.
Scale - 1/2" = 1 mile
July, 1970 Data

Figure 2

Profile of Control Data



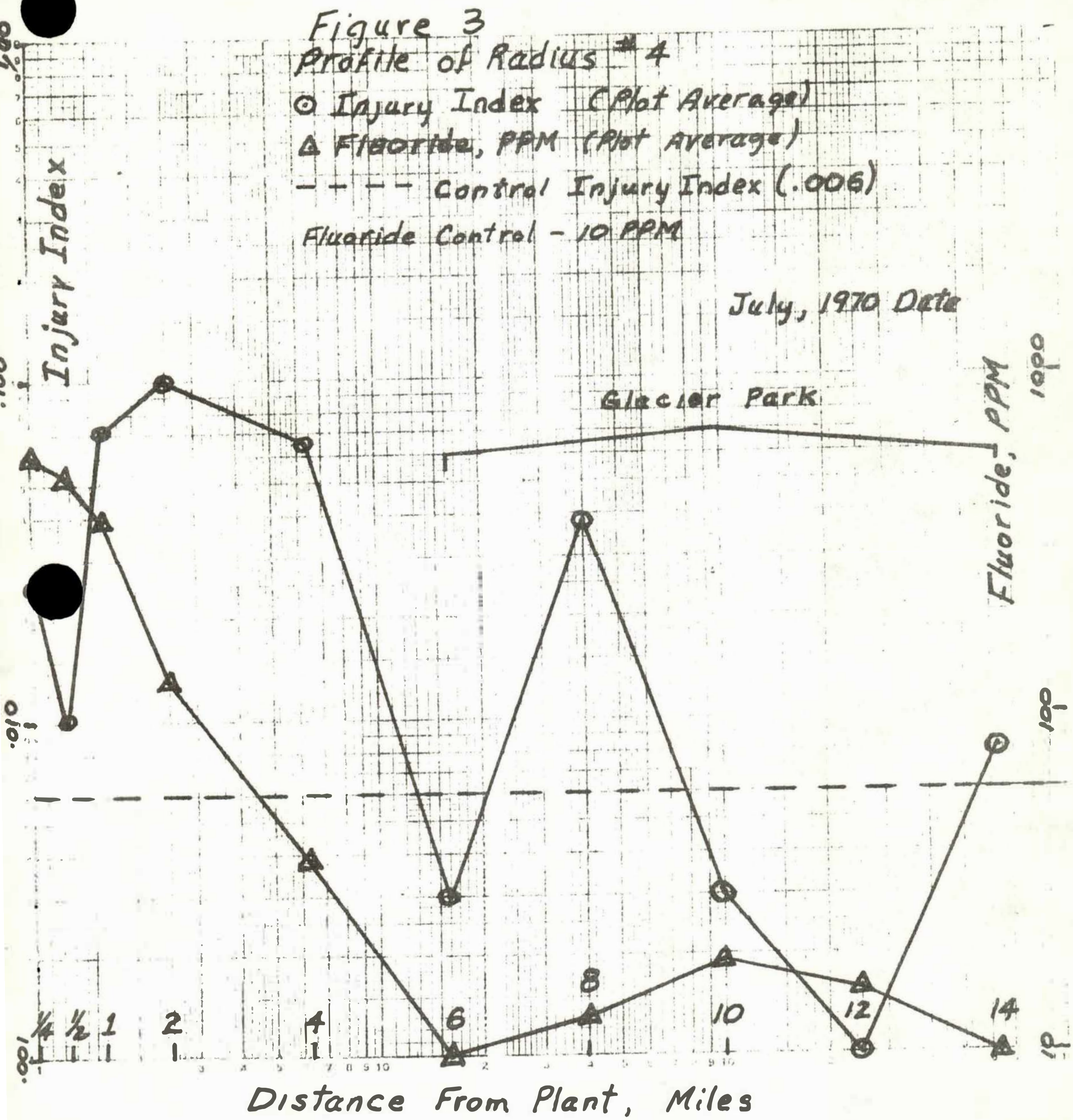


Figure 3
Profile of Radius #4
Injury Index (Plot Average)
Fluoride, PPM (Plot Average)
Control Injury Index (.006)
Fluoride Control - 10 PPM
July, 1970 Data
Glacier Park
Injury Index
Fluoride, PPM
.100
.010
.001
1000
100
10
1/4
1/2
1
2
4
6
8
10
12
14
Distance From Plant, Miles

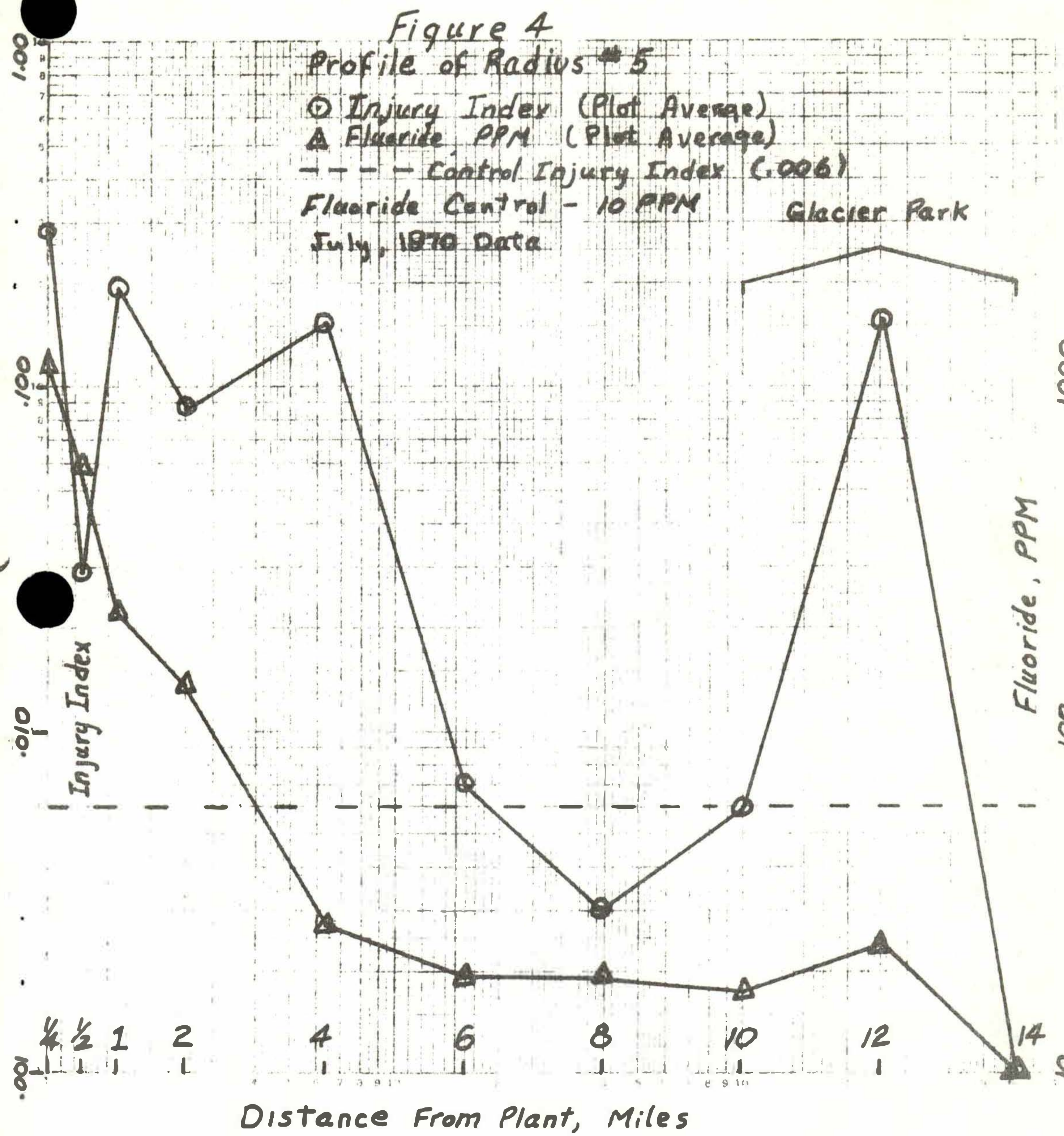


Figure 4
Profile of Radius #5
Injury Index (Plot Average)
Fluoride PPM (Plot Average)
Control Injury Index (.006)
Fluoride Control - 10 PPM
July, 1970 Data
Glacier Park
1.00
.100
.010
.001
Injury Index
1000
100
10.
Fluoride, PPM
1/4
1/2
1
2
4
6
8
10
12
14
Distance From Plant, Miles

Figure 5

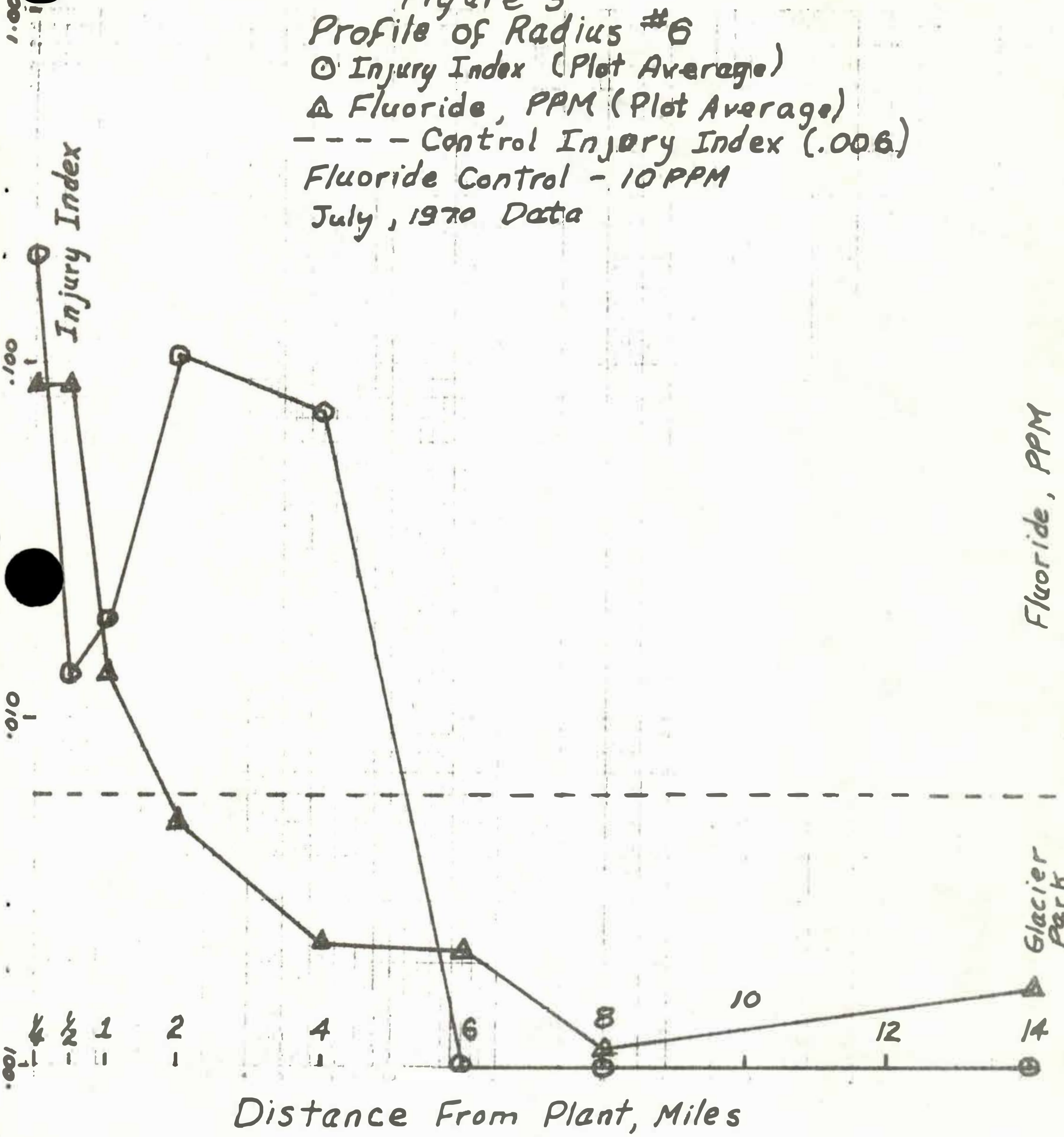

Profile of Radius #6
Injury Index (Plot Average)
Fluoride, PPM (Plot Average)
Control Injury Index (.006)
Fluoride Control - 10 PPM
July, 1970 Data
Injury Index
1.00
.100
.010
.001
Fluoride, PPM
1000
100
10
Glacier Park
¼
½
1
2
4
6
8
10
12
14
Distance From Plant, Miles

Table I.--Summary of control data

A. By vegetation type[1/]

Vegetation	Mean	Standard error	Confidence interval
Shrubs	6.78	1.200	4.19 - 9.37
Conifers (1969)	6.31	1.010	4.13 - 8.49
Conifers (1970)	6.84	.933	4.83 - 8.85
Herbs	8.69	1.500	5.22 - 12.16
Grass	8.90	3.170	-- --
Total	7.10	.545	6.00 - 8.20

1/ All values are p.p.m. fluoride.

B. By plot

Plot No.	Average fluoride	Average I.I.
1	6.92	0.006
2	4.79	.000
3	8.02	.000
4	10.36	.000
5	7.03	.007
6	5.80	.006

Table II.--Summary of radial and special sample data pertinent to Glacier National Park

Distance from source (miles)	Radius 4		Radius 5		Radius 6	
	Average fluoride	Average I.I.	Average fluoride	Average I.I.	Average fluoride	Average I.I.
¼	604.14	0.025	1181.50	0.288	875.30	0.202
½	537.60	.010	597.80	.029	877.60	.033
1	397.25	.072	224.20	.197	138.20	.019
2	130.23	.150	130.70	.086	51.17	.106
4	38.16	.066	27.80	.151	23.00	.073
6	10.13	.003	19.93	.007	21.40	.000
8	13.25	.038	19.60	.003	11.75	.000
10	19.68	.003	17.43	.006		
12	16.98	.000	24.33	.115		
14	6.88	.008	7.46	.000	17.83	.000

Special sample number	Species	Fluoride	I.I.	Location
9	Oregon grape	9.0	0.102	Old Flathead RS, GNP
11	Lodgepole pine (1969)	15.0	.175	Old Flathead RS, GNP
	Lodgepole pine (1970)	3.3	.005	Old Flathead RS, GNP
12a	Ceanothus	11.0	.013	Old Flathead RS, GNP
15	Douglas-fir (1969)	28.0	.122	Old Flathead RS, GNP
	Douglas-fir (1970)	7.3	.000	Old Flathead RS, GNP
16	Douglas-fir (1969)	66.3	.330	Old Flathead RS, GNP
	Douglas-fir (1970)	13.0	.000	Old Flathead RS, GNP
33.5	Lodgepole pine (1969)	21.3	.010	2 mi. NE of Flathead RS on face of Apgar Mountains at 3,900 ft. m.s.l.
	Lodgepole pine (1970)	5.3	.000	Same as above
35	Ponderosa pine (1969)	10.0	.000	Same as above
	Ponderosa pine (1970)	5.5	.000	Same as above